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DESIGN OPTIMISATION OF A DISC AND PRESSURE DROP BEHAVIOR OF A PISTON CHECK VALVE

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ABSTRACT

A piston check valve comes under a Check Valve category, which normally allows fluid to flow through it in only one direction. Piston check valves are generally used to protect pumps or similar equipment, allowing the flow in only one direction and preventing flow reversal due to back pressure. The piston check valves are designed with globe valve bodies, producing an increased drop pressure in the pipeline. This design provides a tight seal as well as a fast reaction to the closure impulse.

In this paper, we present design optimization of a disc and pressure drop behavior of a piston check valve which we supplied to a client of size DN25 x CL150 by completing all the tests as per the standards and valve is dispatched to the client location after post installation due to some practical requirement client needed more outlet pressure from the valve, but changing the valve with different valve and change the size of the valve is not possible as the whole project installation is already done. After several discussions with client, we decided to change the geometry of internal part of the valve.

In order to achieve that we created three-dimensional numerical simulations and flow setup arrangements like fitting, setup for air and liquid sources, setup for digital reading of pressure by using differential pressure gauges. We did numerical calculations which shows the behavior of the flow in client service condition.

Based on the values obtained from the above steps, we finalized the disc design which will give required outlet pressure and we send the finalized disc to client location for approval. This design is finalized, which gives a maximum flow rate as per the client requirement and we got approval from the client and we delivered the updated design to site successfully.

KEYWORDS: Piston Check Valve, CFD, Pressure Drop & Flow Coefficient (CV)

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Original Article

INTRODUCTION

Check valves allow flow in one direction and automatically prevents back flow (reverse flow) when fluid in the line reverses direction. They are one of the few self-automated valves that do not require assistance to open and close. Unlike other valves, they continue to work even if the plant facility loses air, electricity [1].

Check valves are found everywhere, including the home. A check valve is probably in the discharge line of the pump. Outside the home, they are found in industries such as automotive, desalination, aviation, commercial construction, water and waste, chemical, colleges and universities, food and beverage, geothermal, hospitals, mining, oil and gas, pharmaceutical, power, pulp and paper, refining, sanitary, marine, steel, tire, and ultrapure water. Like other valves, check valves are used with a variety of media: liquids, air, other gases, steam, condensate,

and in some cases, liquids with fines or slurries. Applications include pump and compressor discharge, header lines, vacuum breakers, steam lines, condensate lines, chemical feed pumps, cooling towers, loading racks, nitrogen purge lines, boilers, HVAC systems, utilities, pressure pumps, sump pumps, wash-down stations, and injection lines [12].

HOW THEY OPERATE

Check valves are flow sensitive and relay on the line fluid to open and close. The internal disc allows flow to pass forward, which opens the valve. The disc begins closing the valve as forward flow decreased or is reversed, depending on design. The function or purpose of a check valve is to prevent reverse flow. Construction is normally simple with only a few components such as the body, seat, disc, and cover. Depending on design, there may be other items such as a stem, hinge pin, disc arm, spring, ball, elastomers, and bearings [2].

PISTON CHECK

Piston, or lift, check valves are available as inclined (Y pattern) or conventional (90 degree) body designs. In either case, a body-guided disc moves within the body bore. The body guide ensures alignment of the seat and disc when the valve closes. Piston check valves are available from 1/4 inch to 24 inches and larger. Smaller valves, 1/4 inch to 2 inches, are normally provided with a spring to assist in closing and to ensure the disc slides back to the seat when installed in vertical lines. The body design selected will determine the pressure drop; inclined design will provide the best floe performance. Piston check valves are available with threaded or socket weld ends or flanged or butt weld ends. Piston check valves can normally be inspected and repaired in line [4].

SELECTION

Among the many factors to consider when selecting a check valve are material compatibility with the medium; valve rating (ANSI); line size; application data—flow, design/operating conditions; installation—horizontal, vertical flow up or down; end connection; envelope dimensions, especially if replacing an existing valve to avoid pipe modifications; leakage requirements; and special requirements such as oxygen cleaning, NACE, CE Mark, etc [12].

LITERATURE SURVEY

- Philip L. Skousen, Revised to include details on the latest technologies, Valve Handbook, Third Edition, discusses design, performance, selection, operation, and application. This updated resource features a new chapter on the green technology currently employed by the valve industry, as well as an overview of the major environmental global standards that process plants are expected to meet. The book also contains new information on: valves used in the wastewater industry, applying emergency shutdown (ESO) valves.
- J. W. Hutchison, This publication was prepared under the direction of the final control elements committee of ISA’s Process Measurement and Control Division. This hand book is intended to acquaint engineers with the factor of control valve design and application and to assist instrument engineers in the selection of the best valve body, actuator and accessories of application.
- Harold J. Hoge, in this publication for each of the gases hydrogen, nitrogen, and oxygen, two charts are given. The first gives directly the number of standards cubic feet of the gas which a cylinder will deliver. The second chart gives values of the compressibility factor $Z=PV/nRT$ and of the density.

DEFINITION

Piston check valve which we supplied to a client of size DN25 x CL150 by completing the all tests as per the standards and valve is dispatched to the client location after post installation due to some practical requirement client needed more outlet pressure from the valve, but changing the valve with different valve and change the size of the valve is notpossible as the whole project installation is already done. After several discussions with client we decided to change the geometry of internal part of the valve. In figure 1 it shows the nomenclature of the piston check valve.

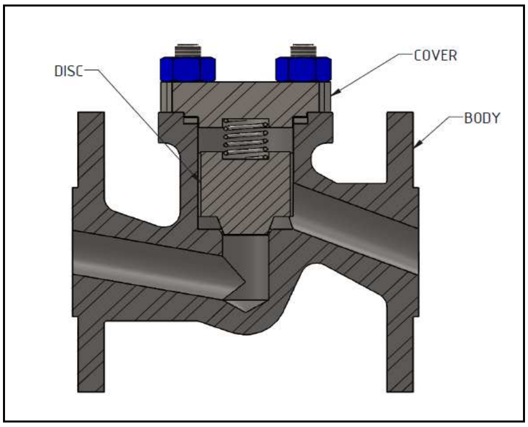


Figure 1: Piston Check Valve Nomenclature (DN25, CL150)

METHODOLOGY

- Test Set up
- FEA Analysis
- Pressure Drop calculation with respect to various Cv Values.
- Testing of valves without restricting flow passageway.
- Testing of Valve with different geometrical condition of disc.

EXPERIMENTAL SETUP

FITTING DESCRIPTION

The hose is connected with 1 inch screwed end floating ball valve at inlet side and this is used to regulate flow at upstream side. The temperature sensor is fitted to measure the temperature of following fluid. Flow meter is attached to measure flow rate of inlet fluid, inlet pressure gauge fitted to measure the inlet pressure of the valve. Outlet pressure gauge fitted to measure the outlet pressure of the valve. The difference between inlet and outlet pressure gives pressure drop across the line. At downstream 1 inch screwed end floating ball valve is fitted and this is used to regulate flow at downstream side.

Load cell and differential pressure gauges are used as an additional attachments which replace pressure gauges and show the digital reading of pressure so it maintain better accuracy level. The load cell is a type of transducer which performs the functionality of converting force into an electric output which can be measured. This type of transducer is highly accurate which provides user with required information that is difficult to obtain by other technology owing to certain commercial factors. The basic flow test system as shown in figure 3.

Figure 2: Test Setup

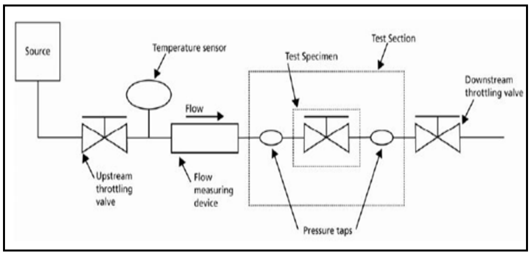
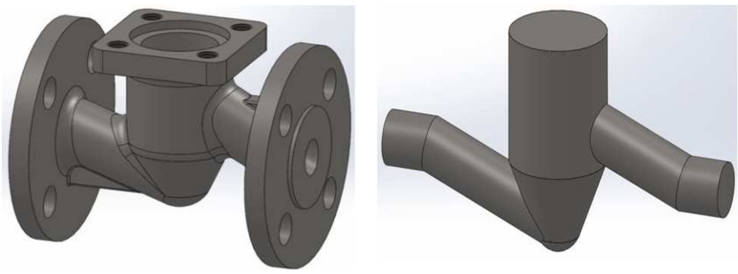


Figure 3: Basic Flow Test System

SIMULATION



(a) **(b)**

Figure 4: (A) Body 3D Model (B) 3D Model of Flow Passage

The finite element analysis is conducted to check the pressure drop with respect to service data, the effect of flow passageway on pressure drop is analyzed by taking various Cv values. We prepared 3D model of flow passage by using Solid Works, and import the model in ansys to perform Analysis in workbench. Mesh the model with proper shape function and define the upstream and downstream arrears and analysis done by using Ansys Fluent.

Steps for analysis

- Flowing Material – Nitrogen
- Define Boundary conditions
- Initialized the solution by using hybrid initialization with 200 number of iteration so we can observe the effect of results in all areas of the body.

PRESSURE DROP WITH RESPECT TO DIFFERENT INLET PRESSURE

Case 1: Inlet pressure -6.8 Kg/cm^2& Flow rate 300Kg/Hrs. **Case 2**: Inlet pressure -8 Kg/cm^2& Flow rate 300Kg/Hrs

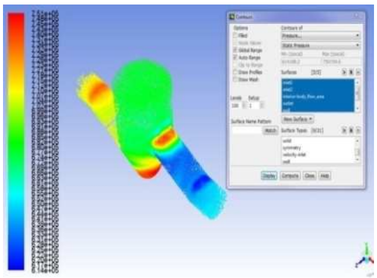


Figure 5:Case1 Inlet Pressure

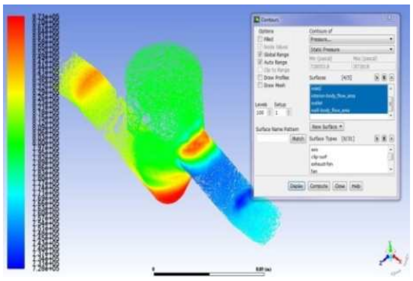


Figure 6:Case2 Inlet Pressure

Case 3: Inlet pressure -7.5 Kg/cm^2& Flow rate 300Kg/Hrs **Case 4:** Inlet pressure -8.5 Kg/cm^2& Flow rate 300Kg/Hrs

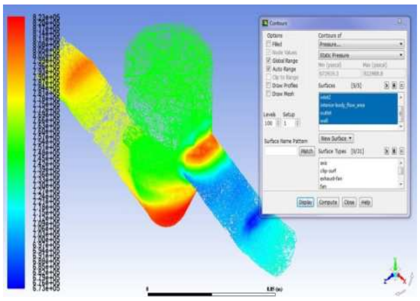


Figure 7:Case3 Inlet Pressure

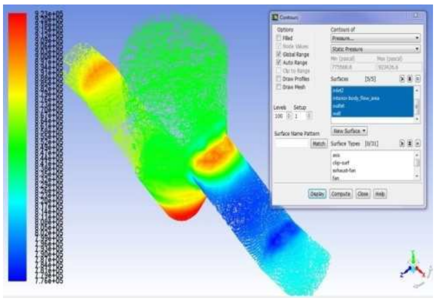


Figure 8:Case4 Inlet Pressure

Case 5: Inlet pressure -7.5 Kg/cm^2& Flow rate 300Kg/Hrs. **Case 6:** Inlet pressure -8.5 Kg/cm^2& Flow rate 300Kg/Hrs

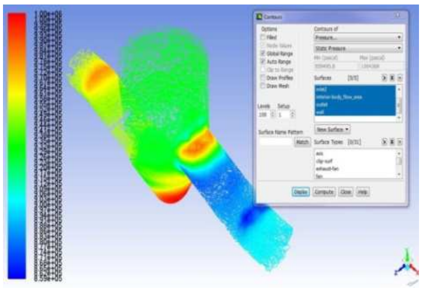


Figure 9:Case5 Inlet Pressure

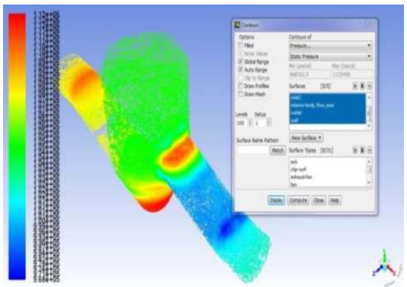


Figure 10:Case6 Inlet Pressure

Table 1: Pressure Drop at Service Condition by Simulation

Case S.no	Flow Rate Kg/Hrs.	Temperature K	Inlet pressure Kg/Cm2	Inlet pressure Pascal	Outlet pressure Pascal	Pressure Drop Pascal	Pressure Drop Kg/Cm2
1	300	315	6.8	666825	614188	52664.2	0.53703
2	300	315	8.0	784532	728054	56478.0	0.57592
3	300	315	7.5	735499	672919	62579.8	0.63814
4	300	315	8.5	833565	775569	57996.3	0.59140
5	300	315	9.3	912018	859496	52522.5	0.53558
6	300	315	10.5	1029698	968302	61396.3	0.62607
7	342	315	6.8	666852	601576	65276.2	0.66563
8	342	315	8.0	784532	726346	58186.0	0.59333
9	342	315	7.3	715885	654843	61042.4	0.62246
10	342	315	8.5	833565	774293	59272.3	0.60441

We verified for all 10 cases with different inlet pressure as mentioned in Table 1 and we concluded that the flow passage is enough to get required pressure at downstream end and to achieve required pressure at the downstream, geometrical changes should be done at disc.

PRESSURE DROP CALCULATED WITH RESPECT TO DIFFERENT CV VALUES

Flow moves through a valve due to a difference between the upstream and downstream pressures, which is called the pressure drop (ΔP) or the pressure differential. If the piping size is identical both upstream and downstream from the valve and the velocity is consistent, the valve must reduce the fluid pressure to create flow by way of frictional losses[1]. A portion of the valve frictional losses can be attributed to friction between the fluid and the valve wall.

Flow coefficient Cv is volumetric flow rate of water at 15.6°C resulting in 1 Psi pressure drop. It is expressed in US gallons per minute.

Table 2: Pressure Drop in Test Setup Case.1 = 5.5 USGPM & Case.2 = 4.5 USGPM

Case 1 Cv = 5.5 USGPM	Flow Rate Kg/Hrs.	Temperature K	Inlet pressure Kg/Cm2	Pressure Drop Kg/Cm2 CASE 1	Case 2 Cv = 4.5 USGPM	Inlet pressure Kg/Cm2	Pressure Drop Kg/Cm2 CASE 2
1	300	315	6.8	0.7743	1	6.8	1.1567
2	300	315	8.0	0.6582	2	8.0	0.9832
3	300	315	7.5	0.7020	3	7.5	1.0487
4	300	315	8.5	0.6194	4	8.5	0.9253
5	300	315	9.3	0.5662	5	9.3	0.8457
6	300	315	10.5	0.5015	6	10.5	0.7491
7	342	315	6.8	1.0063	7	6.8	1.5032
8	342	315	8.0	0.8553	8	8.0	1.2777
9	342	315	7.3	0.9374	9	7.3	1.4003
10	342	315	8.5	0.8050	10	8.5	1.2026

After verifying results of pressure drop in both case 1 & case 2 the case 2 Cv value gives more pressure drop compared to case 1. “Hence the Cv value should be more than4.5 USGPM. The flow performance shall be verified with testing with various geometrical conditions of disc”.

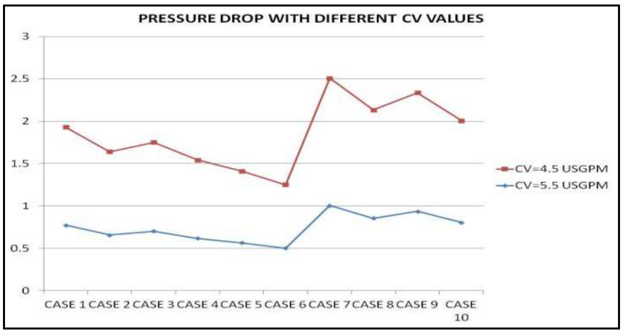


Figure 11: Pressure Drop Comparison of Case1 and Case 2

TESTING OF VALVE WITHOUT RESTRICTING FLOW PASSAGEWAY

First the valve is tested with no restriction condition so additional pressure drop due to disc can be observed. With the reference of below table the further Cv values of modified disc can be observed and the experiment is to be done up to

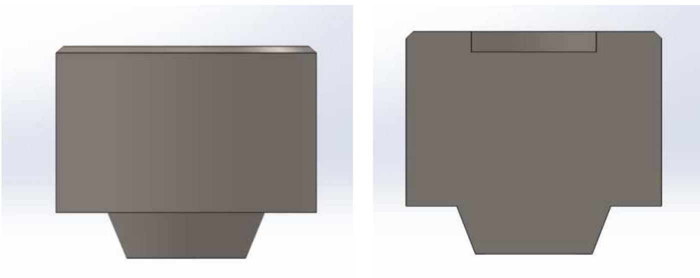
the disc design with higher Cv value is arrived.

Table 3: Flow Coefficient of Valve Without Restricting

Pressure Drop Kg/Cm2	Flow Rate Lit./Min.	Cv USGPM
0.3	48	6.1
0.3	47.3	6
0.3	46.8	5.9
0.25	41	5.7
0.25	39	5.4
0.25	40.2	5.6
0.2	36	5.6
0.2	36.6	5.7
0.2	36.2	5.6
0.1	30	6.6
0.1	29	6.4
0.1	29.4	6.5

TESTING OF VALVE WITH DIFFERENT DISC

The test is carried out on the supplied disc which has weight of 216.89 grams. Below images shows the geometry of disc.



(a) **(b)**

Figure 12: (a) Disc Isometric View (b) Sectional View

Table 4: Pressure Drop in Case 1 Disc Test Setup

Pressure Drop Kg/Cm2	Flow Rate Lit./Min.	Cv USGPM
0.4	20	2.2
0.4	20	2.2
0.4	20	2.2
0.3	19	2.4
0.3	18.2	2.3
0.3	18.4	2.3
0.25	18.1	2.5
0.25	17.9	2.5
0.25	17.9	2.5
0.2	17.8	2.8

In second case, the disc is modified to reduce its weight by decreasing height of disc, inside drill length is also increased and four relief holes are drilled from side section instead of top. So, weight of modified disc is reduced to 140

grams. In the third case, the disc is further modified for seating profile. The seating profile is changed to Parabolic shape to avoid turbulence occurred into the flow. Now the weight of modified disc is 92.937 grams. Images below show the geometry of the disc.

Finally, in the fourth case the disc is modified in such a way that the flow has some restriction at the collar of disc and the hole is drilled below the collar so flow pass away with minimum lift of disc ultimately force required to lift the disc is reduced and get maximum flow at downstream end. Now the weight of modified disc is 125.02 grams. Images below show the geometry of the disc. In Table 6 case 4 test results.

As per the table 6 Case 4 designs are finalized, which gives a maximum flow rate.

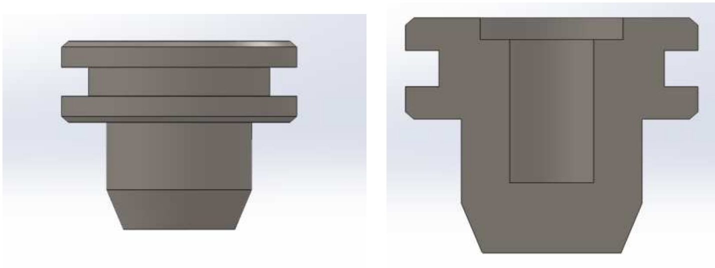


Figure 13: Modified Disc (Finalized Disc)

Table 5: Pressure Drop in Case 4 Disc Test Setup

Pressure Drop Kg/Cm2	Flow Rate Lit./Min.	Cv USGPM
0.4	35.4	3.9
0.4	35.2	3.9
0.4	35.4	3.9
0.3	34.2	4.3
0.3	34.2	4.3
0.3	34.1	4.3
0.25	32.5	4.5
0.25	32.3	4.5
0.25	32.4	4.5
0.2	31.2	4.8

RESULTS & DISCUSSIONS

The above methodology for the disc design optimization and pressure drop behavior for a piston check valve has been systematically investigated by comparing the Numerical, simulation and experimental setup the conclusion are drawn as follows. Case 4 disc give the maximum outlet pressure as per the client requirement.

Following are the outcome from above study

- Disc design is finalized which gives maximum flow rate.
- Similar design is used for DN40 Valve.
- Both Samples are sent on site to confirm the performance of disc.
- After conformation from client spare required are send on site.

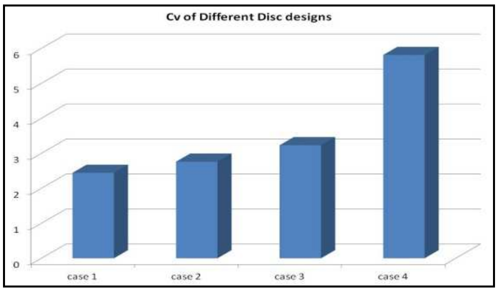


Figure 14: Average Cv values of All 4 Cases

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ABOUT COMPANY

Hawa Valves are manufacturers and exporters of valves for application in critical hydrocarbon/oil and gas upstream, midstream, downstream, chemical, power, marine, mining and general industry. Hawa Valves have ISO 9001. ISO 14000, OHSAS 18000, SIL 3, CE/PED, ATEX certified and have American Petroleum Institute monogram licenses of API 600, API 6A, API 6D, API 6DSS and API 609.

The dedicated in house R&D facility is recognized by Government of India, Ministry of Science and Technology, Department of scientific and Industrial Research. Hawa Valves hold many international patents.

"Hawa Valves India Pvt. Ltd. As a company is ready to meet all control valves needs in any environment or filed"

CONCLUSIONS

Likewise, through a whole array of accomplishment, including our vision, enthusiasm, flexibility, innovation product development and use of technology diversity of exports, emphasis on quality and shrewd business acumen indeed seems assured of a very bright future.

For more details: http://www.hawavalves.com/

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